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Effectiveness of Glyphosate Mixed With Soil-Active Herbicides

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SUMMARY

Broadcasting mixtures of glyphosate and soil-active herbicides over loblolly pine (*Pinus taeda* L.) seedlings may control established weeds and emerging weed seedlings better than either glyphosate or soil-active herbicides alone. However, herbicides will injure young pines if applied improperly. To examine seedling injury, we broadcast two rates of glyphosate, 0.4 and 0.8 lb acid equivalent per acre, alone and mixed with hexazinone, oxyfluorfen, or simazine, over newly planted loblolly pine seedlings and herbaceous competitors. Oxyfluorfen and simazine did not increase pine mortality, but glyphosate alone or in mixtures did. Glyphosate and hexazinone applied alone or mixed produced the most promising results for weed control.

Keywords: Herbaceous weed control, hexazinone, loblolly pine seedlings, oxyfluorfen, *Pinus taeda* L., simazine.

INTRODUCTION

Diameter and height growth of loblolly pine (*Pinus taeda* L.) seedlings can be increased by controlling herbaceous competitors in newly established plantations (Bacon and Zedaker 1987, Nelson and others 1981, Tiarks and Haywood 1986), and weed control may be especially important when converting pasture to pine stands (Haywood 1988, Yeiser and others 1987). Several herbicides are available for controlling weeds on forest sites. However, certain plants, such as established bluestem (*Andropogon* spp. and *Schizachyrium* spp.), are difficult to control with most available soil-active herbicides, and if dosages are increased to obtain satisfactory weed control, pine seedling injury may increase as well.

If established bluestems are present, weed control can be obtained with a nonselective herbicide, such as glyphosate (N-[phosphonomethyl]glycine), or with disking before the pines are planted (Haywood 1988). However, neither disking nor a glyphosate treatment provides residual control of emerging seedling weeds, and postplant weed control may still be needed the next spring.

If difficult-to-control weeds become established after pine seedlings are planted, perhaps using a mixture of herbicides will avoid overapplication of any one chemical. For example, glyphosate could be mixed with a soil-active herbicide and broadcast early in the growing season from April through June. Glyphosate should control established weeds, and the soil-active herbicide should provide residual weed control during this growth period, which is critical for the pine seedlings. Glyphosate can injure pine seedlings, as will other herbicides, but such injury may be avoided if the herbicide rates are low enough.

To examine weed control and loblolly pine seedling tolerance to selected herbicide treatments, two rates of glyphosate, 0.4 and 0.8 lb acid equivalent (a.e.) per acre, alone or mixed with one of three soil-active herbicides, were evenly broadcast over newly planted seedlings and competing vegetation in April 1982. For comparison, the soil-active herbicides were applied alone on other plots in February 1982, and there were untreated check plots.

METHODS

Study Sites and Treatments

The study was replicated on two sites. Site one was a Beauregard silt loam (Plinthaquic Paleudult, fine-silty, siliceous, thermic) at the J.K. Johnson Tract, Palustris Experimental Forest, Sec. 4, T2N, R3W, Rapides Parish,

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Louisiana. Site two was a Kolin silt loam (Glossaquic Paleudalf, fine-silty, siliceous, thermic) on the Kisatchie National Forest, Evangeline Ranger District, Compartment 45, Sec. 31, T2N, R2W, Rapides Parish, Louisiana. Both were gently sloping (1 to 3 percent), moderately well-drained upland sites, but each site had different cover conditions because of different management histories.

Site one had supported a stand of slash pine (*P. elliotii* Engelm. var. *elliotii*). This stand was clearcut in 1973, and the residual trees and logging debris were single-chopped with a rolling drum chopper. The vegetation was unrestrained except for periodic controlled burns to reduce fire hazards. Because of burning, vegetation at one site initially was a heavy rough of established bluestem and panicum (*Panicum* spp. and *Dichanthelium* spp.) grasses, forbs, blackberry (*Rubus* spp.), and scattered tree and shrub sprouts (*Liquidambar styraciflua* L., *Myrica cerifera* L., and *Rhus copallinia* L.). The rough was disked before the study began.

Site two was heavily grazed by cattle and had supported a stand of loblolly pine. This stand had been clearcut in 1980 and the residual trees and logging debris single-chopped with a rolling drum chopper and control burned that fall. Grazing continued, and the vegetation initially was a low cover of common carpetgrass (*Axonopus affinis* Chase), other grasses, forbs, blackberry, and scattered tree and shrub sprouts.

In January 1982, at each site, 12 treatments (11 chemical treatments plus 1 check) were established in a randomized complete block design with 10 blocks. Blocks were established because of site variation and to simplify treatment and measurement. Plots were circular 20 square foot areas, and plot centers were located on a 10- by 10-foot spacing. Two 1-0 bare-root loblolly pine seedlings were planted about 1 foot apart in the center of each plot.

Treatments

Herbicides were broadcast evenly over the pine seedlings, competing vegetation, and plot surface in a 25 gallons per acre water solution. Application was made with a hand-pump sprayer. A plastic-lined cylinder was used to delineate each plot's perimeter and to prevent drift. The 11 chemical treatments applied at each site included 2 concentrations of glyphosate, 0.4 and 0.8 lb a.e. per acre, alone or mixed with 1 of 3 soil-active herbicides: simazine (6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine), hexazinone (3-cyclohexyl-6-[dimethylamino]-1-methyl-1,3,5-triazine-2,4[1H,3H]-dione), and oxyfluorfen(2-chloro-1-[3-ethoxy-4-nitrophenoxy]-4-[trifluoromethyl]benzene). For comparison, the three soil-active herbicides were also applied alone, and there were untreated check plots. The per-acre treatment schedule was as follows:

Soil-active herbicides broadcast on February 23, 1982

1. Simazine at 5.0 lb active ingredient (a.i.)
2. Hexazinone at 1.0 lb a.i.
3. Oxyfluorfen at 1.0 lb a.i.

Mixtures broadcast on April 26, 1982

4. Simazine at 5.0 lb a.i. and glyphosate at 0.4 lb a.e.
5. Hexazinone at 1.0 lb a.i. and glyphosate at 0.4 lb a.e.
6. Oxyfluorfen at 1.0 lb a.i. and glyphosate at 0.4 lb a.e.
7. Simazine at 5.0 lb a.i. and glyphosate at 0.8 lb a.e.
8. Hexazinone at 1.0 lb a.i. and glyphosate at 0.8 lb a.e.
9. Oxyfluorfen at 1.0 lb a.i. and glyphosate at 0.8 lb a.e.

Glyphosate broadcast on April 26, 1982[1]

10. Glyphosate at 0.4 lb a.e.
11. Glyphosate at 0.8 lb a.e.

[1] Certain glyphosate products are labeled for herbaceous weed control in plantations of loblolly pine seedlings at 0.4 to 0.6 lb a.e. per acre when mixed with sulfometuron methyl. Application is made when the competing vegetation is growing actively. For loblolly pine release from woody competitors, glyphosate is applied in the fall at 1.1 to 1.5 lb a.e. per acre after seedlings have been established for more than 1 year. Certain glyphosate-product labels do not permit direct application to the foliage or stem of crop trees.

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On February 23, 1982, the relative humidity was 45 percent during treatment. Soil moisture was at field capacity. The sky was clear to partly cloudy, and there was no rain. Winds were 1 to 5 miles per hour. Daytime temperatures ranged from 40 to 80 °F. Treatments were finished by 12:00 p.m. On April 26, 1982, the relative humidity was 45 percent during treatment. Soil moisture was at field capacity. The sky was clear, and there was no rain. Winds were 5 to 15 miles per hour. Daytime temperatures ranged from 60 to 85 °F. Treatments were finished by 1:00 p.m.

Measurements and Data Analysis

On September 17, 1982, survival of loblolly pine seedlings was noted, and herbaceous plant cover was estimated ocularly to the nearest percentage. Numbers of surviving pine seedlings per plot were arranged in r by c contingency tables and analyzed by chi-square tests for independence. For each site, the rows were treatments, and the columns were the three survival classes: no seedlings, one seedling, and two seedlings. The weed control percentages were compared by analysis of variance and Duncan's Multiple Range Tests ($p = 0.05$).

RESULTS AND DISCUSSION

Pine Survival

At both study sites, the February treatments of oxyfluorfen and simazine alone did not adversely affect pine survival (table 1). Hexazinone alone may have caused a slight, but insignificant, reduction in pine survival compared with the checks; the labeling warns that some pine mortality may occur when hexazinone is used as a broadcast treatment. In another study (Haywood 1988), hexazinone, oxyfluorfen, and simazine, applied alone during the first, second, and third growing seasons after planting, respectively, did not injure loblolly seedlings.

At both study sites, the April treatments with glyphosate alone adversely affected seedling survival compared with the checks, and the high rate of glyphosate (0.8 lb a.e. per acre) was more detrimental than the low rate (0.4 lb a.e. per acre) (table 1). Others have shown detrimental effects to loblolly seedlings from April applications of glyphosate mixed with sulfometuron methyl (Yeiser and others 1987) and from glyphosate broadcast at 0.4 to 1.5 lb a.e. per acre during the first growing season after planting, regardless of the date of application (Haywood and Melder in press).

At site one, the mixtures of hexazinone and oxyfluorfen with the low rate of glyphosate adversely affected pine survival, and the degree of effect was similar to that for the low rate of glyphosate alone (table 1). At site two, these two mixtures were very detrimental.

At site one, the mixture of simazine with the low rate of glyphosate did not adversely affect pine survival compared with the checks, even though glyphosate alone was detrimental to survival (table 1). At site two, however, this mixture of simazine with glyphosate was very detrimental, so no particular significance was given to the results at site one.

At both study sites, the mixtures of hexazinone and simazine with the high rate of glyphosate adversely affected pine survival, and the degree of effect was similar to that for the high rate of glyphosate alone (table 1). The mixture of oxyfluorfen and the high rate of glyphosate was very detrimental, a fact that may indicate a chemical synergism, particularly because oxyfluorfen alone was very safe to use.

Pine seedling survival was generally lower at site two (40 percent) than at site one (62 percent). The chief difference was greater mortality on the chemically treated plots at site two (table 1). Heavy cattle grazing may have been a contributing factor because seedlings under stress, possibly from trampling and increased exposure to wind and extremes in temperature, are more susceptible to chemical injury. However, the influence of grazing, if any, was not examined rigorously.

Weed Control

At site one, herbaceous plants covered 98 percent of the check plots by the end of the growing season (table 2). Because of grazing, vegetation was more sparse at site two, and herbaceous plant coverage on the checks was 75 percent. Greater weed cover usually indicates that control will be more difficult, but in this study, hexazinone or simazine alone and all of the herbicide mixtures were more effective at site one than site two. Perhaps the low cover of common carpet grass, other grasses, and forbs at site two was more difficult to control than the bluestem, panicum, and forb cover at site one. Bluestem is susceptible to glyphosate, and in one study (Haywood 1988), hexazinone, oxyfluorfen, and simazine were used effectively on the type of vegetation at site one if the established cover was first controlled by disking or broadcasting glyphosate before planting pine seedlings.

At site one, oxyfluorfen alone significantly reduced herbaceous plant coverage to 80 percent, and simazine alone reduced coverage to 13 percent (table 2). At site two, neither oxyfluorfen nor simazine alone significantly controlled competitors.

At both study sites, the other chemical treatments were more effective than either oxyfluorfen or simazine alone (table 2). Glyphosate and hexazinone alone or mixed reduced herbaceous plant coverage to 1 to 3 percent at site one and 10 to 33 percent at site two. The mixtures of oxyfluorfen or simazine with glyphosate were as effective as the hexazinone and glyphosate treatments, but these results could be attributed to glyphosate alone.

Table 1.—*Distribution of plots by the number of surviving loblolly pine seedlings arranged in an r by c contingency table*

Site, application date, and treatment	Classes of surviving seedlings per plot			
	0	1	2	Total
	Number of plots/class			
Site one*				
February 23, 1982				
Simazine at 5.0 lb a.i. per acre	0	2	8	10
Hexazinone at 1.0 lb a.i. per acre	0	5	5	10
Oxyfluorfen at 1.0 lb a.i. per acre	0	0	10	10
April 26, 1982†				
Simazine-glyphosate (0.4 lb)	0	3	7	10
Hexazinone-glyphosate (0.4 lb)	4	1	5	10
Oxyfluorfen-glyphosate (0.4 lb)	3	5	2	10
Simazine-glyphosate (0.8 lb)	2	7	1	10
Hexazinone-glyphosate (0.8 lb)	1	6	3	10
Oxyfluorfen-glyphosate (0.8 lb)	8	2	0	10
Glyphosate at 0.4 lb a.e. per acre	3	3	4	10
Glyphosate at 0.8 lb a.e. per acre	4	5	1	10
Check	0	2	8	10
Expected number of plots/class	2	3	5	10
Site two*				
February 23, 1982				
Simazine at 5.0 lb a.i. per acre	0	3	7	10
Hexazinone at 1.0 lb a.i. per acre	0	4	6	10
Oxyfluorfen at 1.0 lb a.i. per acre	1	1	8	10
April 26, 1982†				
Simazine-glyphosate (0.4 lb)	7	3	0	10
Hexazinone-glyphosate (0.4 lb)	4	6	0	10
Oxyfluorfen-glyphosate (0.4 lb)	6	3	1	10
Simazine-glyphosate (0.8 lb)	9	1	0	10
Hexazinone-glyphosate (0.8 lb)	8	2	0	10
Oxyfluorfen-glyphosate (0.8 lb)	10	0	0	10
Glyphosate at 0.4 lb a.e. per acre	3	4	3	10
Glyphosate at 0.8 lb a.e. per acre	8	2	0	10
Check	1	1	8	10
Expected number of plots/class	2	3	5	10

* Site one chi-square = 72.6 with 22 degrees of freedom ($p<0.001$), and site two chi-square = 92.2 with 22 degrees of freedom ($p<0.001$).

† In all mixtures, the rate of application is 5.0 lb a.i. per acre for simazine and 1.0 lb a.i. per acre for hexazinone and oxyfluorfen. For glyphosate, (0.4 lb) means 0.4 lb a.e. per acre and (0.8 lb) means 0.8 lb a.e. per acre.

Table 2.—*Herbaceous plant cover at the end of the first growing season*

Application date and treatment	Mean plant cover*	
	Site one	Site two
	------ *Percentage* ------	
February 23, 1982		
Simazine at 5.0 lb a.i. per acre	13c	78a
Hexazinone at 1.0 lb a.i. per acre	1d	33b
Oxyfluorfen at 1.0 lb a.i. per acre	80b	65a
April 26, 1982†		
Simazine-glyphosate (0.4 lb)	2d	18b
Hexazinone-glyphosate (0.4 lb)	1d	17b
Oxyfluorfen-glyphosate (0.4 lb)	1d	12b
Simazine-glyphosate (0.8 lb)	1d	14b
Hexazinone-glyphosate (0.8 lb)	1d	10b
Oxyfluorfen-glyphosate (0.8 lb)	2d	13b
Glyphosate at 0.4 lb a.e. per acre	3d	27b
Glyphosate at 0.8 lb a.e. per acre	2d	29b
Check	98a	75a

* Within each column, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests ($p = 0.05$).

† In all mixtures, the rate of application is 5.0 lb a.i. per acre for simazine and 1.0 lb a.i. per acre for hexazinone and oxyfluorfen. For glyphosate mixtures, (0.4 lb) means 0.4 lb a.e. per acre and (0.8 lb) means 0.8 lb a.e. per acre.

CONCLUSIONS

In the first growing season after planting, broadcast treatments with hexazinone, oxyfluorfen, or simazine alone did not significantly reduce loblolly seedling survival. Glyphosate, either alone or mixed with these other herbicides, generally caused too much seedling mortality to recommend broadcast application of glyphosate at rates even as low as 0.4 lb a.e. per acre during the spring after planting.

Oxyfluorfen or simazine alone was less effective than hexazinone for controlling the competing vegetation. Glyphosate and hexazinone applied alone or mixed provided acceptable weed control throughout the growing season. A mixture of these two chemicals should have more applications than either chemical alone, and this mixture, presently labeled for pine release under certain conditions, deserves further study as a site preparation or directed-postplant treatment.

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